Appendix A – Lovberg Paper

FIXED POINT-TO-POINT OPERATIONS IN THE 71.0-76 GHz AND 81.0-86 GHz BANDS

By John A. Lovberg, Ph.D.[1]

Long thought to have limited use, the 71-76 and 81-86 GHz upper millimeter wave bands are in fact ideal for providing wireless connections to the Internet backbone at data rates up to 12.5 Gbps and at distances up to ten miles. Use of this upper millimeter wave spectrum will be a powerful tool in closing the data divide because it will bring high speed wireless data services to areas where it is simply too costly to install optical cable. Moreover, as discussed below, point-to-point use of this upper millimeter wave spectrum will *not* preclude other uses of the spectrum.

This paper is being submitted to the FCC in support of the Petition For Rulemaking filed by Loea Communications LLC ("Loea"). Loea is a subsidiary of Trex Enterprises Corporation ("Trex"). Trex Enterprises specializes in Government and commercial research and development in the field of applied physics.

I. An Overview Of Loea's Millimeter Wave Technology

Loea has developed a high-speed, high-throughput, gigabit wireless point-to-point technology that is designed to take advantage of the propagation characteristics of the 71-76 GHz and 81-86 GHz bands. This technology can be used to complement and supplement the fiber optic network by extending fiber capacity 10 miles beyond the final strand of fiber.

Loea's equipment is capable of meeting the current Gigabit Ethernet standard of 1.25 Gbps of full-duplex data transmission by using a small portion of these bands. In July of 2001, Loea began testing and demonstrating the capabilities of its equipment by interconnecting its Maui headquarters in Kihei, Hawaii with its remote processing facility 1.7 miles away. In addition to high-speed file transfer and teleconferencing capabilities, the 1.25 Gbps wireless data link provides high-speed Internet access to the remote site, originating from a hardwired DS3 (45 Mbps) Internet connection in the headquarters building. In support of a limited experiment, the remote site has been upgraded to act as a hub for distribution of broadband access, using the Outrigger Hotel on the Wailea shores as the first beta site and demonstrating Internet access,

1 Dr. John Lovberg received his BS degree in Physics from the California Institute of Technology in 1981, and his Ph.D. in Astrophysical Sciences from Princeton University in 1987. He has since accumulated 14 years of experience in microwave and millimeter-wave research and development for pulse power and nuclear fusion diagnostics, passive radiometric imaging, and communications.

video on demand, and teleconferencing capabilities. While the initial data-rate requirements of the Outrigger (10 Mbps) required only a commercially available 5.8-GHz RF link from the hub, the proven capacity of Loea's 70 GHz technology will allow for future expansion, both at the Outrigger and to the other 11 resort hotels on the Wailea shores.

Loea's wireless communication demonstration in Maui uses a highly directional millimeter-wave (MMW) dish antenna and a low-noise amplitude-modulated transceiver. The commercial prototype links transmit and receive over separate channels at 71.00-72.75 and 73.00-74.75 GHz, using simple on-off keying. Two feet in diameter, the dish antennas generate pencil-like beams only 0.36 degrees wide. At the receiver, 1.7 miles away, this translates to an illuminated footprint extending only 28 feet radially from the antenna. Even so, a second dish antenna placed within this radius at the remote hub reuses the spectrum without interference, simply by pointing in a slightly different direction (less than 5 degrees away). The narrow beam delivers 240 Watts ERP from only a 5 milliwatt transmitter. At 70 GHz, this power level provides reliable link performance through heavy fog and light rain, while the beam diameter is sufficiently large to be unaffected by the occlusions of birds or leaves.

Although Loea's success in Maui demonstrates it can meet today's data standards, it is already working to develop equipment to reach the future Gigabit Ethernet standard of 12.5 Gbps. Further near-term development, along with hardware implementation of phase-shift keying for improved spectral efficiency, will increase data rates to 12.5 Gbps, making it possible for wireless technologies to meet the increasing demand for data backhaul that will be required within the next five to ten years.

II. THE 71-76 AND 81-86 GHZ UPPER MILLIMETER WAVE BANDS ARE UNIQUELY SUITED FOR HIGH BANDWIDTH WIRELESS TRANSMISSIONS

A. Significant Bandwidth

The millimeter wave spectrum above 70 GHz (70,000 MHz) is currently an open frontier because this frequency space marks the limits of today's semiconductor technology. The allocated band between 71 and 76 GHz alone contains more bandwidth than the combined bandwidth of all of the MMDS, LMDS, and DEMS bands at 10,550-10,680 MHz, 12,500-12,700 MHz, 17,700-19,700 MHz, 24 GHz, 27,500-28,350 MHz, 29,100-29,250 MHz, 31,000-31,300 MHz, and 38.6-40.0 GHz. In addition, the FCC frequency allocation above 70 GHz is uncluttered with prior services, so modern needs and applications can be addressed without concessions to historical restrictions.

The directivity of a pair of dish antennas of a given size scales with the fourth power of frequency (a pair of two-foot dishes, which provides a combined 70 dB of gain at 11 GHz) represents over 100 dB of gain at 71 GHz For this reason, millimeter wave antenna beams resemble laser beams, and do not interfere like more-typical RF emissions at lower frequencies. This means that MMW service rules can authorize fixed point-to-point radio operation over extremely wide bandwidths but over very narrow geographical areas ("pipes"), without precluding other utilization of the same band by any other technology, service or provider. In other words, using judicious service rules and band etiquette, a widely available bandwidth can be authorized for fixed point-to-point operation, and it will never need to be "taken back," even if the bandwidth utility eventually becomes obsolete or new services are implemented in the spectrum.

B. Atmospheric Window Considerations

The "atmospheric window" between the oxygen absorption lines near 60 GHz and that at 118 GHz, in which Millimeter wave radiation propagates with minimal loss, is generally accepted to have its lowest attenuation at 94 GHz. This frequency has been exploited by the military for high-frequency radar, and research from universities to large semiconductor houses has been focused at 94 GHz. However, as illustrated in figure 1, while clear weather atmospheric absorption (air at 15°C and 10% relative humidity) shows a minimum near 94 GHz, in poorer conditions, such as fog or light rain, this minimum moves to a significantly lower frequency near 70 GHz.

Figure 1

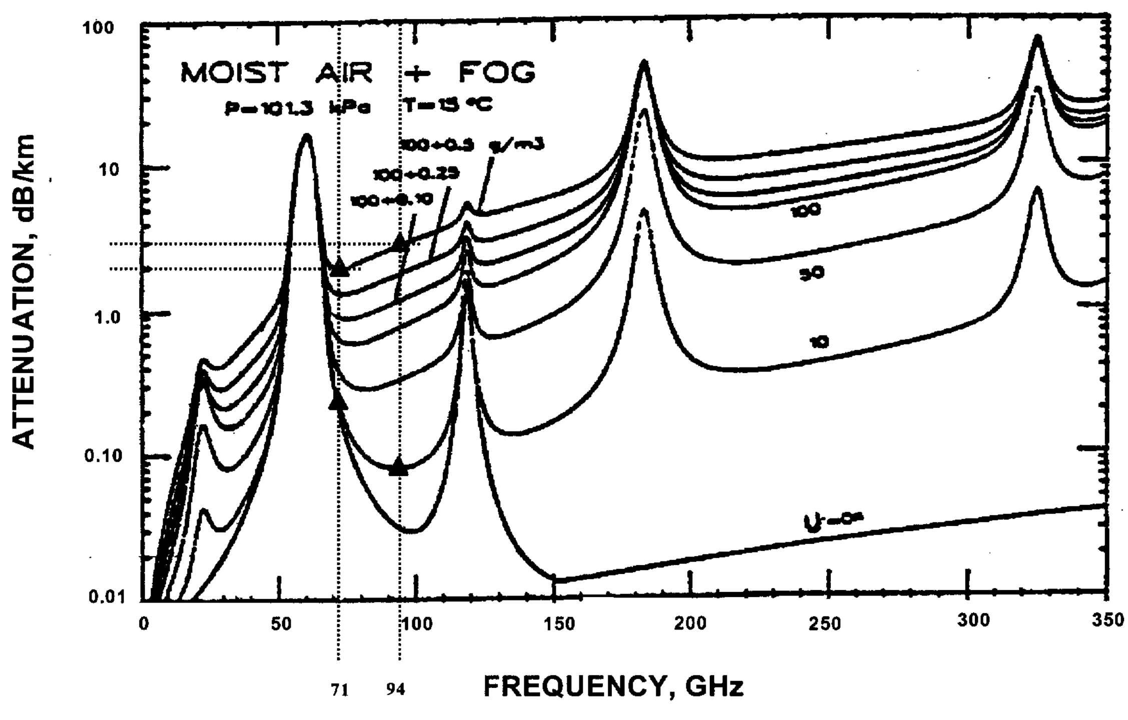

Figure 1. MMW attenuation in the atmosphere at 15°C: the W-band "window" has minimum attenuation at 94 GHz in clear, dry air (10% relative humidity), but this minimum moves down to 71 GHz in heavy fog. In fog, the attenuation at 71 GHz is 2 dB/km, versus 3 dB/km at 94 GHz.

To effectively serve suburban communities that are beyond the reach of metropolitan-area fiber loops, wireless link ranges of up to 10 miles will be required. Table 1 compares atmospheric attenuation for various weather conditions in the 71-76, 81-86, and 92-95 GHz bands. In heavy fog, figure 1 shows that atmospheric attenuation at 94 GHz is 1 dB per kilometer greater than atmospheric attenuation at 74 GHz. This is insignificant for "last mile" wireless technology serving short distances in metropolitan areas, but it translates to 50 times more path attenuation over a 10 mile link to a community "outside of the beltway." This demonstrates the higher utility of the 71-76 GHz and 81-86 GHz bands, relative to the spectrum above 90 GHz, for long-range communications. Over the FCC's entire current spectrum allocation, the band from 71 to 76 GHz is the single band that provides the longest-range operation in all weather while simultaneously affording sufficient bandwidth for Gigabit Ethernet operation. The band from 81 to 86 GHz is the first runner-up.

Table 1. 10-MILE ATMOSPHERIC PATH LOSSES IN dB

WEATHER CONDITION / FREQUENCY	71-76 GHz	81-86 GHz	92-95 GHz
Dry Air, 5% RH, 15°C, 1013 mbar	2	1.5	1
Normal Air, 50% RH, 15°C, 1013 mbar	6	6	7
Saturated Air, 100% RH, 15°C, 1013 mbar	12	12	15
Heavy Fog, 100% RH + 0.5 g/m^3 water vapor, 15°C, 1013 mbar	34	42	51
Light Rain, 1.5 mm/hr, 100% RH, 15°C, 1013 mbar	33	36	42
Heavy Rain, 100 mm/hr, 100% RH, 15°C, 1013 mbar	>400	>400	>400

The differential in path loss (as reflected above) between a 70 or 80 GHz carrier and a 90 GHz carrier in heavy fog affords the 70 and 80 GHz links several advantages. First, transmitter power can be kept low (typically tens of milliwatts), reducing component cost while increasing reliability and minimizing radiated power density. Secondly, the resulting increase in signal-to-noise ratio enables the use of sideband filtering and quadrature phase-shift keying to achieve higher rates of data transmission within a given bandwidth. Thirdly, the lower dynamic range between good- and bad-weather extremes (*e.g.*, 32 dB versus 50 dB) improves link stability.

C. Interference Considerations – Loea's Equipment Will Cause Little or No Interference

The 71-76 GHz and 81-86 GHz bands provide the opportunity not only for many point-to-point operations to share the spectrum, the propagation characteristics of this band make it ideally suited to allow more than one type of service to share this spectrum as well. Above 70 GHz, narrow radiating beams allow unlimited reuse of the frequency spectrum. Even if an incumbent service provider is operating thousands of point-to-point-licensed links within a certain city, a competitive service provider can enter the same market at any time with a better product and/or better pricing.

As demonstrated by Loea in Hawaii, even in the unlikely incident that two receiving stations terminate within the beamwidth of a single transmitter (tens to a hundred feet in radius from beam centerline), only a receiver pointed exactly at the subject transmitter will receive the transmitted signal. Figure 2 illustrates this point. Signal "pipes," characterizing the extent of radio-frequency emissions along the lines of sight between transceiver pairs, can cross (a) or even terminate (b) at a single point without interference. The only restriction is that both ends of one link cannot coincide with both ends of another (c). Even should this *extremely* unlikely situation arise, a midpoint relay (d) can be used to redirect one link along a non-parallel path.

Figure 2

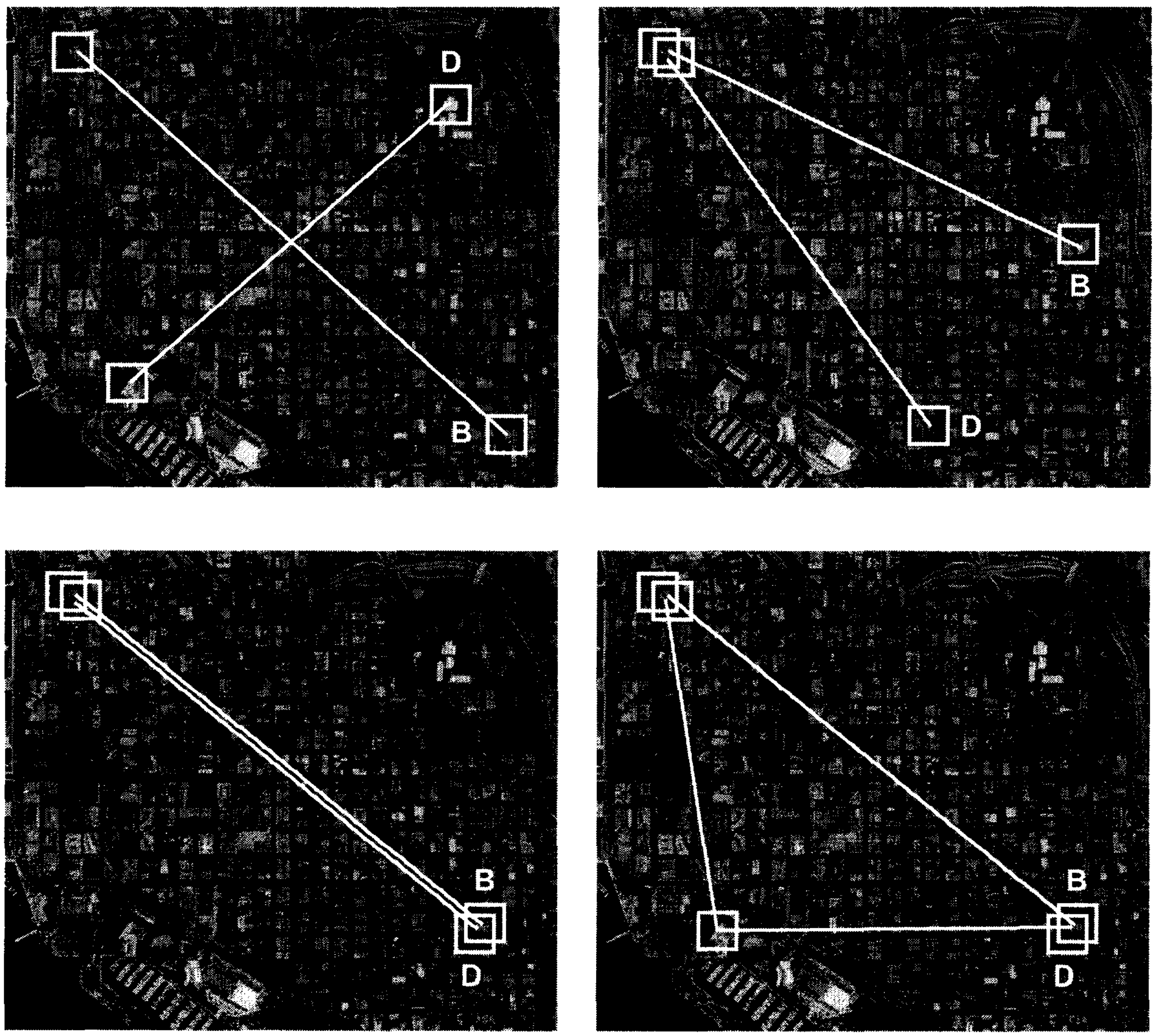

Figure 2. Signal "pipes," characterizing the extent of radio-frequency emissions along the lines of sight between transceiver pairs, can cross (a) or even terminate (b) at a single point without interference. The only restriction is that both ends of one link cannot coincide with both ends of another (c). Even should this *extremely* unlikely situation arise, a midpoint relay (d) can be used to redirect one link along a non-parallel path.

III. Proposed Revisions to Part 101

FCC Part 101 rules relating to point-to-point communications are generally appropriate for the 71-76 and 81-86 GHz bands as well. As specified below, revisions to Part 101 to cover these new bands will take the form of additions, rather than exceptions.

In order to allow point-to-point operations with the greatest throughput, rules for the 71-76 GHz band and the 81-86 GHz band should include minimal restrictions on spectral use. Restrictions on total radiated power and antenna directionality are needed, as they affect the likelihood of signal interference, and thus the ability to share the spectrum between service users and between types of service. Other restrictions, such as spectral partitioning and bandwidth efficiency requirements, would limit the ability of hardware and service providers to evolve to meet growing bandwidth requirements in the future (beyond about 5 years).

Specifically, Part 101.113(a), which sets upper bounds on transmitter power, should add the frequency bands 71,000 to 76,000 MHz and 81,000 to 86,000 MHz, and keep the maximum EIRP of +55 dBW, commensurate with all other transmission above 19.7 GHz. Part 101.115(c), which sets antenna beamwidth minima, should specify 0.6 degrees half-power beamwidth (HPBW) and 50 dBi gain for both frequency bands, in both congested (Category A) and non-congested (Category B) areas; this gain is 12 dB higher than other bands above 19.7 GHz, thus enabling the spatial-parceling paradigm. Part 101.109(c), dealing with maximum authorized bandwidth, should specify a maximum authorized bandwidth in each new band of 5,000 MHz. Part 101.141, which sets minima for spectral efficiency of digital transmissions, currently applies only to transmissions below 19.7 GHz, and should continue to except the new bands.

IV. Looking Toward the Future

By 2007, Gigabit Ethernet for local backhaul is expected to give way to the next-generation 10-Gigabit Ethernet standard, with its 12.5 Gbps data rate requirement. Although the 71.00-72.75 and 73.00-74.75 GHz segments used in Loea's Maui demonstration are quite sufficient to provide wireless communications using current Gigabit-Ethernet standards, they have insufficient bandwidth to achieve 12.5 Gbps. High-order QAM modulation techniques, already problematic at low frequencies, are impractical above 70 GHz, where small atmospheric changes can cause large amplitude swings in very short times. Sideband filtering or quadrature phase-shift keying (QPSK) techniques can deliver up to 2 bps per Hz of available bandwidth. Allowing for a cushion at band edges, the unpartitioned 71-76 GHz band and the unpartitioned 81-86 GHz band could each deliver 6.25 Gbps, and these two channels of data could be buffered to meet the 10-Gigabit Ethernet standard. Polarization diversity could be added to separate the transmit- and receive channels.

A. Band Parceling Increases Complexity and Reduces Efficiency

The usual motivation for segmenting an allocated frequency band is to eliminate interference by assigning separate channels to different services. In order for as few as two users to utilize the same airspace, the minimum bandwidth needed for each service must be less than one-half of the allocated band. This is not the case here (even at 2 bps per Hz, more than 60% of the allocated bandwidth is required for each 10-Gigabit service, and 8PSK, QAM16 and higher order quantization are impractical at 70 GHz). More importantly, since the basis for non-interference in sharing the airspace at these frequencies is through parceling of *physical* space rather than *frequency* space, subdividing the band serves no purpose. To the contrary, partitioning the 71-76 GHz band, even in a manner consistent with the present needs of the Gigabit Ethernet standard, could make the band obsolete within 5 years, whereas leaving it unrestricted will extend its usefulness indefinitely. Subdividing the MMW bands leads to lower overall bandwidth efficiency, due to the need for "bumper bands" between channels. Using four channels, for instance 71.00-72.75, 73.00-74.75, 81.00-82.75, and 83.00-84.75 GHz, a transceiver could still theoretically deliver 12.5 Gbps full-duplex operation, with the use of sharp edge filtering, QPSK, 4-channel buffering, and polarization diversity. However, this and every additional segmentation of the band increases system complexity and reduces total available bandwidth, with no tangible benefit. At some level of subdivision it becomes impossible to deliver the 10-Gigabit Ethernet data rate at all.

By 2012, when 100-Gigabit Ethernet becomes the backhaul standard, MMW wireless communications must move into the 100-300 GHz range to find sufficient bandwidth. Because these frequencies are not appropriate for long-distance backhaul (due to excessive atmospheric attenuation), the 71-76 and 81-86 GHz bands will still be needed to provide long-range operation at 10 Gbps. By this time, optical fiber may obsolete many wireless runs, but the spectrum need never be reallocated, since those still using it for point-to-point wireless communications will never interfere with other future uses of the band.

V. Conclusions

Under this proposal, the needs of providers and users of ultra-broadband wireless digital communications will be served for the foreseeable future with this simple band allocation and judicious associated common-carrier service rules:

2001	71-76 GHz	Modified Part 101 licensing
	81-86 GHz	Modified Part 101 licensing
2010	200-270 GHz	Modified Part 101 licensing

The center frequency of the highest-frequency band can be changed without significant effect, so an exact band specification here is not needed at present. On the other hand, since both the 71-76 and 81-86 GHz bands could be used right now to provide wireless Gigabit Ethernet, this proposal recommends that licensing procedures and service rules be established immediately for both bands.

Appendix B – HAI Paper

Economically Efficient Licensing of the Millimeter Wave Band

A. Daniel Kelley
HAI Consulting, Inc.

Prepared for Loea Communications Corporation

September 5, 2001

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Economically Efficient Licensing of the Millimeter Wave Band

A. Daniel Kelley
HAI Consulting, Inc.

I. Introduction and Summary

I have been asked by Loea Communications Corporation ("Loea") to consider alternatives for licensing spectrum in the 71 to 76 and 81 to 86 GHz bands. I conclude that deployment of the wireless technology developed by Loea has the potential to produce substantial benefits for consumers. Loea's licensing proposal will allow the technology to be deployed efficiently and rapidly. Competitive bidding for the spectrum needed by Loea and its potential competitors is not necessary and would likely be counterproductive. The conditions under which spectrum auctions produce public benefits are simply not present given the nature of the spectrum involved and technology that will be used. An auction will only cause delay and may lead to an inefficient market structure. The existing model for point-to-point microwave licensing can be adapted to licensing the applications proposed by Loea.

II. Qualifications

I am Senior Vice President of HAI Consulting, Inc. ("HAI"), an economics, technology and public policy consulting firm. I conduct economic and policy studies on a wide variety of telecommunications issues, including local exchange competition, wireless competition, cable television regulation, dominant firm regulation, and the cost of local service. I have testified on telecommunications issues before the Federal Communications Commission and the California, Colorado, Connecticut, Florida, Georgia, Hawaii, Maryland, Massachusetts, Michigan, Nevada, New York, Oregon, Pennsylvania, Utah and Washington Commissions, as well as the Federal-State Joint Board investigating universal service reform.

I have extensive experience with wireless industry public policy issues. My firm has advised various wireless industry clients on auction and entry strategies. I have filed numerous Declarations in Commission and U.S. District Court proceedings involving wireless issues on behalf of a variety of clients. Finally, I have been involved in wireless industry cost modeling projects undertaken by my firm.

I have advised foreign government officials, incumbents, and new entrants on telecommunications policy matters and have taught seminars in regulatory economics in a number of countries including Australia, Canada, Chile, the Czech Republic, Mexico, New Zealand, Poland, the Slovak Republic and Slovenia.

My professional experience began in 1972 at the Antitrust Division of the U.S. Department of Justice where I analyzed mergers, acquisitions and business practices in a number of industries, including telecommunications. While at the Department of Justice, I was a member of the U.S. v. AT&T economics staff. In 1979, I moved to the Federal Communications Commission ("FCC") where I held positions as Senior Economist in the Common Carrier Bureau and the Office of Plans and Policy, and also served as Special Assistant to the Chairman. After leaving the FCC, I was a Project Manager and Senior Economist at ICF, Incorporated, a public policy consulting firm. From September 1984 through July of 1990, MCI Communications Corporation employed me as its Director of Regulatory Policy. I received a Bachelor of Arts degree in Economics from the University of Colorado in 1969, a Master of Arts degree in Economics from the University of Oregon in 1971 and a Ph.D. in Economics from the University of Oregon in 1976. My resume is attached.

III. Loea Proposal

Loea is a subsidiary of Trex Enterprises Corporation, a firm that engages in substantial communications and defense related research and development. Loea is requesting that the Commission adopt service rules to open the 71-76 and 81-86 GHz bands for commercial deployment of point-to-point broadband gigabit wireless access. In particular, Loea has developed high-speed, high-throughput, gigabit wireless technology that uses "pencil-beam" waves that can provide wireless connections to the Internet backbone.[1] Loea's service can provide the "last mile" or last "ten miles" to extend broadband capability at speeds that will initially reach 1.25 Gbps, and will ultimately reach the 12.5 Gbps standard that is currently under development. Business or government organizations that do not currently have access to fiber will be the logical customers for this service.

Firms operating in this segment would provide point-to-point fixed millimeter wave wireless service. According to Loea, the size of the allocation is necessary to allow for flexibility as the technology develops. While a narrower allocation might provide the frequency diversity needed to provide reliable and efficient transmission at 1.25 Gbps speeds, the evolving 12.5 Gbps standard will require substantial additional spectrum.[2] Licensing (as opposed to unlicensed operation) is necessary to provide customers a guaranty of interference free service. Licensing is also critically important to the potential investors who will be supplying the capital necessary to build out the facilities.

Fixed uses are already allowed in the 71.0-75.5 segment and the remaining spectrum – 75.5-76.0 – is included in the World Radiocommunications Conference-2000 ("WRC-2000") proposal.[3] There are potential radio astronomy applications in a portion of the band. However, Loea believes that any interference concerns can be dealt with through frequency coordination. The 81-86 GHz band is already available for the fixed applications contemplated by Loea. Service rules are necessary to provide for the licensing of the Loea service (and other non-interfering services).

Frequency coordination and licensing could be performed by the Commission or by a private third-party coordinator. If a third-party coordinator were chosen, it would be financed by payments from firms who are granted licenses and would effectively become the band manager for the spectrum. The

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1 John A. Lovberg, *Fixed Point-to-Point Operations in the 71.0-76.0 GHz and 81-86 GHz Bands,* ("*Loea Technical Paper*").

2 *Id.*

3 See FCC WRC-2000 Home Page, Current United States Draft Proposals, September 13, 1999, p. 104. http://www.fcc.gov/WRC-00/welcome21.html

existing Universal Licensing System could be used after frequency coordination by a third-party.

IV. Benefits of the Loea Proposal

The Loea proposal provides for substantial consumer benefits. Encouraging the development and deployment of new communications technology and allowing the spectrum resource to be productively applied to meet market demand are two of the principal goals of national spectrum policy.[4] The Loea proposal does both. The Loea technology allows for development of a portion of the spectrum that has not been used for commercial purposes, primarily due to prior technical constraints. As discussed further below, the service proposed has the potential to satisfy currently unmet consumer demand.

The end result is likely to be a significant enhancement of consumer welfare that fully complies with Chairman Powell's market oriented policies. Consumers will have greater choice. Entrepreneurs will be given opportunity to build new businesses based on innovation. Finally, market forces rather than government fiat will determine the outcome.[5]

Extending fiber optic capacity to individual buildings is quite expensive. As a result, existing fiber networks reach only a limited number of end users, and

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4 *See* Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium, Policy Statement, Released November 22, 1999.

5 *See* Remarks by Chairman Michael Powell before the Federal Communications Bar Association, Washington D.C. June 21, 2001.

these are primarily large business users in the core urban areas of major cities.[6] Fixed wireless services are currently being offered in lower frequency bands. Under current rules, these services can potentially provide an efficient and cost-effective alternative for data links in urbanized areas or mass market broadband Internet access, but generally do not allow speeds as high as those that Loea will transmit. In addition, the available spectrum for these services is obviously limited. Multipoint Microwave Distribution Service ("MMDS") is being configured as a valuable mass-market alternative to digital subscriber line ("DSL") and cable Internet access, but provides transmission speeds well below the Gigabit-plus rate that Loea technology will provide to larger business and government operations.[7] The business plans of Teligent and Winstar, two leading fixed wireless carriers, have encountered difficulty.[8]

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6 CLEC fiber loops are in core business areas because the economics of deploying fiber simply do not support construction in less densely populated areas. FCC data support this conclusion. According to the most recent FCC data, CLECs have gained an 8.5 percent market share. However, they serve less than three percent of total lines with their own last mile facilities. See FCC, Common Carrier Bureau, Industry Analysis Division, Local Telephone Competition: Status as of December 31, 2000, May 2001, p. 1 and Tables 3-4. It is reasonable to infer that the residential and small business lines that CLECs serve are provisioned mainly over ILEC unbundled network elements.

7 Moreover, recent developments in the cable industry have lead analysts to question the rate at which the cable infrastructure upgrades necessary to provide advanced services over cable infrastructure will take place. See AT&T-Comcast Deal Could Set Back Telephone, Cable Convergence, Wall Street Journal, July 12, 2001, p. B1.

8 *See* Winstar Seeks Accelerated Exit from Chapter 11, August 1, 2001 Company Press Release and Teligent announces Delisting from the Nasdaq National Market, June 7, 2001 Company Press Release.

An additional technology for extending broadband to smaller cities and rural areas will obviously produce benefits in terms of potentially addressing the so-called digital divide. Fiber optic backbones often traverse smaller towns but getting fiber to individual buildings is prohibitively expensive with wireline technology. Wireless technologies generally do not require the scale and scope of wireline alternatives. The Loea technology is particularly useful for this purpose because it can be deployed at relatively small scale. Therefore, Loea technology will provide cost-effective broadband and higher transmission to businesses, schools, libraries and hospitals in these areas.

The Loea proposal also has the potential to enhance competition, which is another important public policy goal. The Loea service will compete with wireline services as well as the wireless services discussed above. This may be particularly important in smaller cities. Incumbent telephone companies did not seriously deploy DSL technology for residential use until cable companies entered the market with high-speed cable modem service. Authorization of the service proposed by Loea may provide the incentive incumbent telephone companies as well as cable and wireless firms need to extend broadband networks to the less densely populated areas.

The Loea technology, due to its scalable nature, will also allow innovative applications not currently contemplated by the incumbent providers. For example, Loea's pencil-beam approach is ideally suited to telemetry. The extremely high bandwidth that the technology produces will also allow next generation video applications that have yet to be developed. The technology may also complement other evolving wireless applications. For example, millimeter wave transmission may provide more efficient backhaul for mobile services.

Finally, the Loea proposal is administratively simple and requires the minimal amount of government involvement necessary to bring commercial applications to the 71-76 GHz and 81-86 GHz bands. Once the proposal is approved, licensing or registration can begin immediately with little additional government involvement. Frequency coordination and licensing in the microwave bands has been successfully implemented with a minimum of Commission oversight or regulation. The Loea proposal also provides the opportunity for minimal involvement. As discussed below, the proposal allows for a neutral third party to be funded by the licensees to undertake coordination and registration of the frequencies.

The Loea proposal does not contemplate competitive bidding for the band. As discussed in the following sections, the service proposed does not appear to be suitable for an auction. All of the public benefits of the new service can be extracted from the simple coordination, licensing and registration plan proposed.

V. The Economics of Competitive Bidding for Spectrum

Auctions are an efficient way to deal with spectrum <u>scarcity</u>. The benefits are by now well known and proven in practice. It is important to remember, however, that spectrum auctions are a means to a result and not an end. The primary economic benefit of spectrum auctions is that it places scarce spectrum in the hands of firms that value it most highly.[9] Generally, the firms that place a highest value on spectrum do so because they believe they are in the best position to provide services that consumers will value highly.

Despite their potential benefits, auctions do not always automatically increase consumer welfare. Consider a case where the demand for spectrum is exceeded by the potential supply. The marginal production cost of the spectrum resource is zero. It becomes valuable only when there is an opportunity cost created by potential alternative uses. In this case, the only circumstance under which an auction will generate revenue is if the supply is artificially restricted in order to create scarcity.

Raising revenue for the Treasury by artificially reducing the amount of spectrum available for sale is not economically efficient. The revenue raised is, in effect, a tax – and an inefficient tax at that. Such a spectrum tax increases the prices that consumers pay and discourages investment in telecommunications. A spectrum tax may also conflict with other public policy goals. For example, by restricting the services that can be offered through the spectrum, competition may be reduced. To the extent entry is discouraged, the ability to meet universal service goals may also be impaired.

The spectrum tax may also discourage the deployment of innovative technology. Implementing new technology is inherently risky. Commission

9 Of course, some firms may value the spectrum highly because their control over it will give them market power or enhance market power they already possess. This is why the Commission has appropriately established spectrum allocations and bidding rules that promote competition.

auctions to date have generally been for services where demand and technology were both well understood by potential market participants. Forcing entrepreneurs to pay a spectrum tax will reduce their incentive to make risky investments.

One response to this line of argument might be that an auction can do no harm. If there is no scarcity, then the price paid will be trivially small. The problem with this argument is that for an auction to succeed, a property right must be defined. Once the property right is defined and granted, then there must be exclusivity. By setting up an exclusivity situation, the auction may create scarcity where none existed before. The auction may raise revenues, but only because of this artificial scarcity. In effect, the user of the spectrum, and ultimately its customers, will be taxed. The owner of the spectrum may not price competitively. Of course, if a large number of competing licenses are auctioned, then this problem will not arise. The result, however, would be very low bids and perhaps no bids on some frequencies. A new auction would be required at a later date if conditions change. In the interim, there will be delay in getting the spectrum to market.

Auctions also have the potential to raise monopoly problems. Firms may value spectrum not because they will use it to provide the most cost-effective and efficient spectrum for consumers, but because it will allow them to protect or extend an existing monopoly position. The Commission response to this problem in the past has correctly been to limit spectrum holdings, to limit the types of firms that can participate in an auction, or to affirmatively encourage smaller firms and new players to bid.

VI. Application of Spectrum Economics to the Millimeter Wave Band

The technology developed by Loea for use in the high frequency spectrum bands drastically reduces the potential for interference between two signals. The highly directional signal travels from source to destination in a narrow beam. This means that a second signal using the same frequencies can serve the building "next door," or even another customer in the same building.[10] In other words, the use of spectrum by carrier A does not prevent carrier B from offering a service in the same general geographic location on the same frequency band.[11] Use of the spectrum by carrier A does not result in an opportunity cost because carrier B is not precluded from offering its own service between virtually the same two points. In such a case, the scarcity basis for bidding on or charging for the spectrum does not exist.

There could, of course, be alternative uses for the spectrum that would lead to contention. This is often the case in lower frequency bands where fixed, mobile and broadcast services vie for the same valuable spectrum. The Millimeter band, however, is virtually virgin spectrum. Given current technology, propagation problems at these high frequencies make the spectrum unsuitable for mobile or broadcast applications.

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10 *Loea Technical Paper* at Section II, C.

11 In practice two signals can interfere if they are close enough together. But two suppliers can easily co-exist in the same band as long as the signals are coordinated.

While the pencil beam technology allows for great "horizontal diversity," the high frequencies will ultimately require the use of the entire bandwidth. In order to propagate reliable signals over reasonable distances in these high frequencies significant bandwidth is required.[12] This is especially true for the 12.5 Gbps services for which standards are currently being developed. Therefore, subdividing channels into multiple bands is not workable.

VII. Frequency Coordination Issues

As described above, with suitable frequency coordination, any contention in the band can be dealt with. The Commission has recently advanced the concept of Band Managers to coordinate the use of spectrum bands on a for profit basis. For example, in the recent 700 MHz auction, frequencies were auctioned to Band Managers whose job it will be to make spectrum available to third parties.[13]

This Band Manager bidding model does not apply here. Once the auction is complete, the band manager becomes a monopolist over the spectrum it has won. Recognizing this, the Commission provided for multiple band mangers, each with a separate slice of the 700 MHz spectrum. As discussed above, technological applications in the in the millimeter band require large "vertical slices" of spectrum, reducing the number of viable spectrum manager allocations. Slicing the spectrum horizontally obviously does not work either. Giving a band

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[12] *Loea Technical Paper* at Section IV.

[13] *See* Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168,

manager exclusive use of the spectrum in a geographic area obviously gives it a monopoly in that area.[14]

There is also a principal-agent problem with the band manger concept. The band manger essentially acts as the Commission's agent in parsing out and charging for spectrum. If it performs this job poorly, there is no effective form of market discipline to remedy the problem. This forces the Commission into a regulatory role.[15]

These potential problems have lead economists to question the efficiency of band manager auctions:

> In promoting secondary markets, the Commission should generally remove restrictions and not mandate the terms upon which spectrum markets emerge. In the 700 MHz Guard Band decision, the Commission has instituted requirements to force a secondary leasing market by mandating that a carrier lease out more than half of its spectrum to unaffiliated entities. While leasing may facilitate efficiency, requiring the operation of a secondary market can reduce efficiency and lead to regulatory game-playing simply to comply with the express provisions of the rules.[16]

Second Report and Order, released March 9, 2000, ("700 MHz Guard Band Order"), para. 2.

14 A theoretical alternative is to have the potential band managers bid not on the price they would pay, but on the terms on which they would make frequencies available to potential users of the spectrum. This "franchise bidding" model would not work here because it would be impossible the Commission to anticipate the appropriate contract terms for a new service that is subject to a high rate of technological change. For a discussion of potential problems with implementing the franchise-bidding model see Oliver E. Williamson, The Economic Institutions of Capitalism (1985), pp. 326-354..

15 *See* Kenneth Arrow, The Economics of Agency, in Principles and Agents: the Structure of Business, J. Pratt and R. Zeckhauser, eds. (1985).

16 *See* Comments of 37 Concerned Economists, In the Matter of Promoting Efficient use of Spectrum Through Elimination of Barriers to the

Then Commissioner Powell expressed similar reservations with mandated band managers in his Separate Statement on the 700 MHz decision.[17]

The model put forth by Loea is a much more practical approach. If the Commission does not want to be in the frequency coordination business for this piece of spectrum (recovering its costs with fees), then a third party could be given the job. Ideally this third party would be free from conflicts of interest.

One model that might be considered is to allow the firms that want to use the spectrum to designate an entity that would provide spectrum management services and contract with it to do so. In order to avoid discrimination problems, a set of simple rules could be applied to the coordinator. In the antitrust sphere, competitive rules joint ventures ("CRJVs") have been used. A joint venture owned by firms that are using licenses in the spectrum would be formed. Any firm that wants to operate in the spectrum band would be able to purchase an ownership interest in the joint venture. By making the coordinator the creature of the potential users of the spectrum, the Commission avoids the problem of having to regulate the band manager. The clients of the coordinator can set the contractual arrangements.

Development of Secondary Markets, WT Docket No. 00-230, February 7, 2001, p. 5.

17 *See* Separate Statement of Commissioner Michael Powell, Dissenting In Part.

VIII. Conclusion

Bringing the Loea technology to market has the potential to provide significant public benefits. This is a case where auctions are not necessary to maximize these public benefits, and would likely be counter-productive. This is because the technology effectively allows virtually unlimited reuse of the spectrum. A license for the narrow geographic path of a pencil beam signal does not exclude others from receiving licenses to provide similar (or differentiated) service in the same general geographic area.

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